Coupled Model for CO_2 Leakage and Seepage

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RESEARCH OBJECTIVES

Geologic carbon sequestration involves the direct injection of large quantities of carbon dioxide (CO_2) into deep geologic formations, such as depleted oil and gas reservoirs, saline aquifers, and unminable coal seams. The accumulation of vast quantities of CO_2 in the deep subsurface entails the risk that CO_2 will leak from the target formation and seep out of the ground. Leakage is CO_2 migration away from the primary target formation, whereas seepage is CO_2 migration across an interface such as the ground surface. The objective of this research is to investigate the leakage, seepage, and dispersion of CO_2.

APPROACH

We have developed a simulation capability called T2CA (TOUGH2 for CO_2 and Air) that is an enhancement of the TOUGH2 reservoir simulator. T2CA includes both subsurface and atmospheric surface layer regions. The approach for the subsurface follows the standard multicomponent and multiphase methods in TOUGH2. For the surface layer, we assume a logarithmic velocity profile to represent time-averaged winds. For atmospheric dispersion, we use the Pasquill-Gifford dispersion curves and Smagorinski Model to estimate dispersivities. The logarithmic velocity profile is specified by setting suitable permeabilities and pressure boundary conditions and setting porosity equal to one. In this way, T2CA can handle coupled subsurface–surface-layer flow and transport. This approach is valid for the case in which CO_2 concentrations in the surface layer are low and mixing is passive. This appears to be a reasonable assumption for the leakage rates expected in geologic sequestration.

ACCOMPLISHMENTS

We have simulated cases of subsurface, surface layer, and coupled flow and transport using T2CA. For the subsurface, we have carried out a sensitivity analysis where various properties of a thick unsaturated zone were varied. In the surface layer, we have carried out verification studies in which we compared our approach with a commercial fluid-dynamics code and observed good agreement. In Figure 1, we present coupled flow results for wind speed equal to 1 m s^{-1} at a height of 2 m.

SIGNIFICANCE OF FINDINGS

As shown in Figure 1, CO_2 concentrations can reach high levels in the subsurface, but are quickly diluted in the surface layer. This result has significance in two important areas of carbon sequestration research: (1) CO_2 sequestration monitoring and verification; and (2) health, safety, and environmental (HSE) risk assessment. For monitoring and verification, our results show that detection is more likely if instruments are placed in the subsurface or in trenches. For HSE risk assessment, our results point to the potentially significant risks of subsurface enclosed spaces, such as basements.

RELATED PUBLICATION

Oldenburg, C.M., and A.J.A. Unger, On leakage and seepage from geologic carbon sequestration sites: Unsaturated zone attenuation. Vadose Zone Journal, 2(3), 287–296, 2003; Berkeley Lab Report LBNL-51928.

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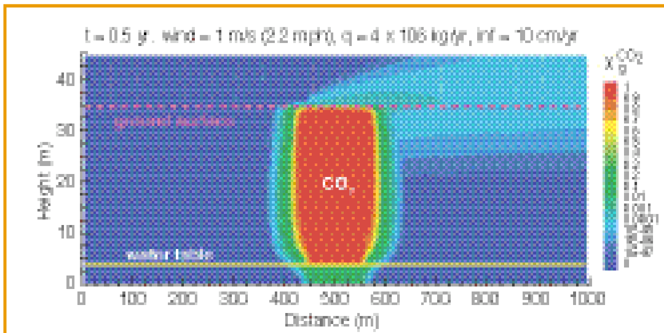

Figure 1. CO_2 mass fraction and gas velocity vectors for a CO_2 leakage scenario involving a source at the water table, with flux equal to 1×10^{-5} kg m^{-2} s^{-1} and wind of 1 m s^{-1} at a height of 2 m from the ground